fauna and flora at the bottom. The details of this work, including maps, graphs and tables, are to be published by the Carnegie Institution of Washington. The relation of local conditions to the precipitation of $CaCO_3$, thus decreasing the depth of the water, is pointed out.

Studies of the effect of these changes on organisms were made. The limiting factor for plants seems to be fixed nitrogen. Only 0.02 mgm. of fixed nitrogen per liter could be determined and it was not thought practicable to determine local changes with certainty. The limiting factor for animals seems to be food. Oxygen could easily become a limiting factor. One kilogram of fish would use up all of the oxygen in 4300 liters of water of the lowest O_2-concentration found at the surface, in twenty-four hours. It seems improbable that fish alone would suffocate, but swarms of Dinoflagellates might suffocate themselves and other animals present.

NOTE ON INTERFEROMETER METHODS OF MEASURING THE ELASTICS OF SMALL BODIES

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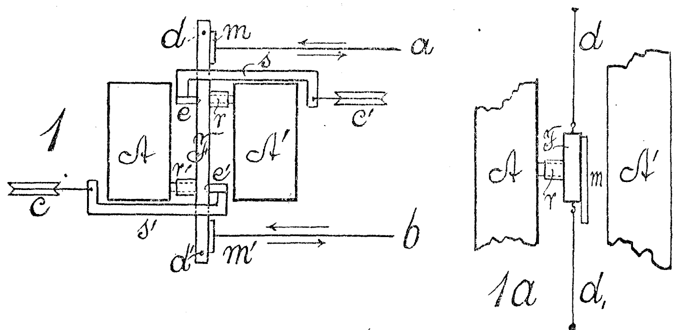
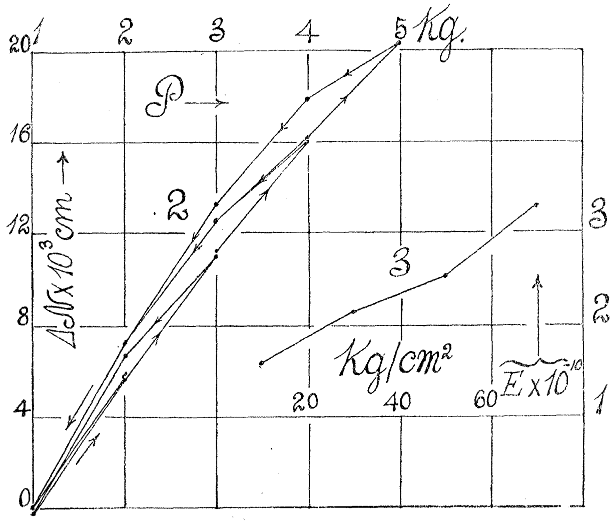
1. *Method.*—At the request of Prof. W. G. Cady, who was in need of Young's modulus in case of certain crystals used in experiments in which he is interested, I endeavored to adapt for this purpose the interferometer heretofore[1] described for measuring small angles with an auxiliary mirror. The project seems feasible and apparently simple in execution, when the method of end thrust indicated in figure 1, is used. Here F is a rigid metallic bar subjected to a force couple, carrying the coplanar mirrors m, m', and capable of rotating slightly in a horizontal plane. These mirrors receive the corresponding rays, a, b, of the interferometer. The force couple is resisted by the resilience of the rods, r, r', to be tested, as these push respectively against the ends of the bar, F, and against the rigid abutments, A, A', of the apparatus. If the force couple changes the bar, F, rotates correspondingly. The component rays, a, b, then register the amount of rotation in the interferometer.

To apply the force couple, weights suspended from the stationary pulleys, c, c', were utilized. These actuate the rectangular offsets, s, s', which force their conical ends, e, e', into corresponding depressions of the bar, F. When not under stress, F is supported by the double

bifilar suspension,[2] the threads of which are attached at d, d'. The abutments were heavy cast iron bricks, $2 \times 3.5 \times 10$ cubic inches in size, firmly bolted together and standing with screws on a smooth bed plate. Thus the apparatus (not including the interferometer) can be rotated around a vertical axis to enlarge the achromatic fringes and around a horizontal axis parallel to F to rotate them. This is necessary for the adjustment.





Omitting details I may add that all measurements were made in terms of the displacement of the achromatic fringes heretofore described.

If E is the traction modulus, l the elongation of each rod of length L, under the force P, and Δ a differential symbol,

$$E = (\Delta P / A) / (\Delta l / L)$$

If the distance apart of the rays, a, b, is $2R$, and of the forces of the couple is $2R'$,

$$2 R \Delta \alpha = \Delta N \cos i,$$

supposing the bar F to rotate over an angle α, in consequence of the increment ΔP of thrust and ΔN to be the corresponding displacement of the micrometer mirror (rays incident at the angle i), needed to restore the interference fringes to their original position. But,

$$\Delta l = R' \Delta \alpha = R' \Delta N \cos i / 2 R$$

so that after reduction

$$E = \frac{2 L R}{A R' \cos i} \frac{\Delta P}{\Delta N}$$

The method will not of course be very precise, because for rods less than an inch long the quantities involved, particularly ΔN, are so small. Any flexure or slight dislocation of the parts of the apparatus are of relatively great consequence. Moreover there is another serious consideration. In long rods the stresses distribute themselves equally throughout the sectional area; but in short rods this is liable not to be the case. There will be lines of longitudinal stress and part of the area, A, may be relatively unstressed. Hence the value of E will come out too small and the question is rather to what degree such a method can be made trustworthy. If the achromatic fringes are used, the optical method as such presents no difficulties. For reasonably thin rods the observed displacement is adequate. The fringes need not be counted and it is even unnecessary to make the method very sensitive. Fringes of moderate size suffice.

The method of flexure would in some respects seem to be preferable. But it is is theoretically less simple and for short rods difficulties similar to the above would be encountered.

2. *Observations.*—In a large number of measurements made with different bodies, the apparatus finally took the form shown in figure 1, in which the rod r, r', to be tested is held by a rigid metallic tube or sheath, in which it fits loosely. Even this can not be employed quite without misgivings; but these must be passed over here. As an example of the results, I will insert graphically the behavior of hard rubber rods, each of about 2.4 cm. long and 0.35 cm. in diameter, thus having a sectional area of about 0.1 sq. cm. and kept under a minimum load of 1 kgm. These were subjected to cyclically varying stress with the results (contractions positive) given in figure 2. With pressures varying in the sequence (1, 2, 3, 2, 1), (1, 2, 3, 4, 3, 2, 1), etc., kgm., the contractions apparently give evidence of well developed hysteresis loops, upon which is super-imposed the continuous viscous deformation which

results from loading. The thrust modulus, E, computed from triplets of data for definite steps of pressure (1, 2, 1), (2, 3, 2), etc., kg. (i.e., 15, 25, etc., kgm. per square centimeter), are given in figure 3. They increase in marked degree with the load. Turning the rods down to smaller diameters successively and testing them in turn, no essential difference in the results was apparent. With rods of high rigidity like glass, brass, steel, only about one-half of the probable modulus can be reached with rods of the above dimensions. The remainder is lost in the small dislocations within the apparatus. These rods[3] must not be more than 1 or 2 mm. thick and enclosed in corresponding sheaths, to be available in an apparatus-like figure 1. Tentative[4] as the results are, however, they are interesting, inasmuch as the dependence of the elastics of a rod on its molecular instabilities will most probably be clearer in case of bodies of light structure like the organic bodies. The whole phenomenon is very much like the condensation of a vapor, requiring higher pressures to condense the instabilities and lower pressures for their release or evaporation, as it were. Deformation proceeds at a rapidly retarded rate through infinite time.[5]

[1] These PROCEEDINGS, 3, 1917, (412).

[2] Shown in the side elevation, figure 1a, with the offsets removed. The fibres d and d_1 are tightly stretched.

[3] Thus in case of steel rods like the above, per kg of load, $\Delta N/\Delta P = 44 \times 10^{-6}$ cm., which is too small for any micrometer.

[4] I have thus far been unable to arrive at a trustworthy distinction, except in magnitude, between the deformations within the apparatus and those of the rods themselves.

[5] From a report to the Carnegie Institution of Washington, D. C.

SUBLACUSTRINE GLACIAL EROSION IN MONTANA

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The mountains of northwestern Montana and northern Idaho are characterized by two classes of deglaciated forms. The forms of one class are the work of relatively small, local glaciers, and are limited to the loftier ranges in which cirques, excavated in the higher slopes, lead down through well-scoured troughs to terminal moraines on the mountain flanks or on the open ground of intermont basins. The forms of the other class are the work of great Canadian glaciers and are limited to the sides and floor of the larger valleys. Two such glaciers crossed the international boundary, as shown in figure 1, truncated the side spurs